Simulating Soil Organic Carbon Sequestration in Cotton Production Systems with EPIC and the Soil Conditioning Index in the Southeastern USA

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Abbreviations:

- CT, Conventional tillage
- NT, no tillage
- SOC, soil organic carbon
- SCI, soil conditioning index
- EPIC, Erosion Productivity-Impact Calculator (renamed the Environmental Policy Integrated Climate) model
- WUE, water use efficiency
- MLRA, Major Land Resource Area.

Management Systems:

1. Monoculture cotton with conventional tillage (CT)
2. Cotton/wheat cover under no tillage (NT)
3. Corn/wheat cover (4-yr)–cotton/wheat cover (4-yr) rotation under NT
4. Bermudagrass (Cynodon dactylon L.) pasture (5-yr)–corn/wheat cover (5-yr)–cotton/wheat cover (5-yr) under NT

MLRAs: (Figure 1)

1. Blackland Prairies in eastern Texas
2. Southern Piedmont in northern Georgia
3. Coastal Plain in South Carolina

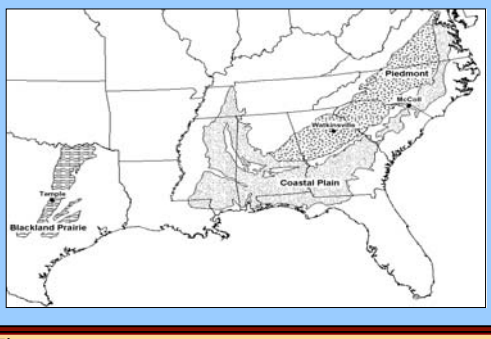
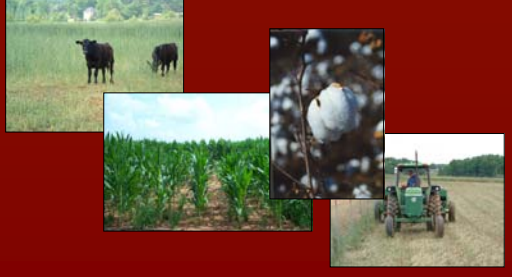


Figure 1.
Location of the three simulation sites within the Blackland Prairies, Coastal Plain, and Southern Piedmont major land resources areas in the southeastern USA.



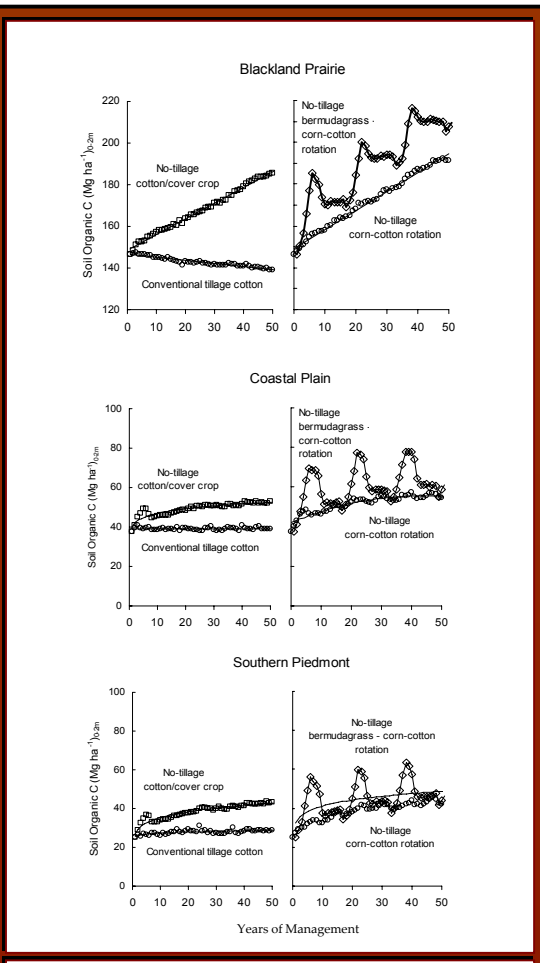


Figure 2.
Simulated soil organic C during 50 years by the EPIC model in three major land resource areas as affected by four management systems.

- From the four management systems on three MLRAs, SCI was linearly related to SOC sequestration simulated by EPIC (Figure 3).
- The greatest deviation from this relationship was in the bermudagrass–corn/wheat cover–cotton/wheat cover system. Excluding this system, the best fit between EPIC and SCI was an exponential growth function that suggested SOC sequestration was insensitive to SCI <0, but increased dramatically with values >0.

The relationships reported in Figure 3 should not be considered quantitative or be used as a predictive tool, since SOC sequestration estimates were obtained only with EPIC v. 3060 and not actual field data.

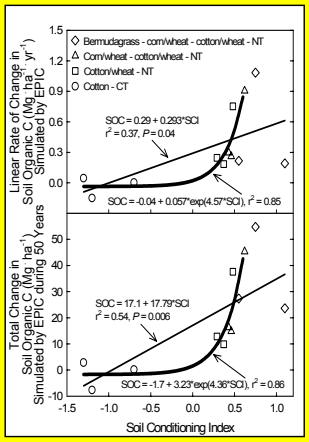


Figure 3.
Soil organic C (SOC) sequestration simulated by the EPIC model in the surface 2 m of soil on a yearly basis (top panel) and throughout a 50-yr period (bottom panel) in relationship with the soil conditioning index. Linear relationships were developed with all 12 observations (4 management systems x 3 major land resource areas). Exponential growth curves were fitted to data, excluding the bermudagrass–corn/wheat cover–cotton/wheat cover system under no tillage (NT).

RESULTS AND DISCUSSION

EPIC simulations of soil organic C

- Organic C content within the surface 2 m of soil increased with time in all management systems, although at a greater rate with NT systems than with CT (Figure 2).
- Within the 2-m profile and averaged across MLRAs, the rate of simulated SOC sequestration was greater under NT management systems than under CT (Table 1).
- There were no differences in the simulated rate of SOC sequestration or total amount of SOC sequestered among the three NT management systems.

	EPIC		SCI
Management system	Linear rate of SOC sequestration (Mg ha^{-1} yr^{-1})	Total quantity of SOC sequestration (Mg ha^{-1})	Unit-less relative change
(1) CT cotton	-0.03	-1.5	-1.07
(2) NT cotton/wheat cover	0.39	20.1	0.38
(3) NT corn/wheat cover–cotton/wheat cover	0.49	25.5	0.50
(4) NT bermudagrass–corn/wheat cover–cotton/wheat cover	0.50	35.3	0.80
Analysis of variance	---------- Pr > F ----------		
CT vs NT systems (1 vs 2-3-4)	0.03	0.008	<0.001
NT ungrazed vs grazed (2-3 vs 4)	0.77	0.16	0.10
NT monoculture vs rotation (2 vs 3)	0.68	0.57	0.58

Table 1.
Estimates of soil organic C (SOC) sequestration (0- to 2-m depth) during 50 years of simulation by EPIC and the Soil Conditioning Index (SCI), averaged across the three simulated Major Land Resource Areas.

EPIC simulations of crop yield and water use efficiency

	Yield		Water-use efficiency	
Management system	Cotton lint	Corn grain	Cotton lint	Corn grain
	--------- Mg ha^{-1} ---------		--------- kg mm^{-1} ---------	
(1) CT cotton	1.41	N.A.	2.45	N.A.
(2) NT cotton/wheat cover	1.15	N.A.	2.29	N.A.
(3) NT corn/wheat cover–cotton/wheat cover	1.32	7.53	2.41	18.5
(4) NT bermudagrass–corn/wheat cover–cotton/wheat cover	1.24	6.90	2.34	17.0
Analysis of variance	---------- Pr > F ----------			
CT vs NT systems (1 vs 2-3-4)	0.06	N.A.	0.22	N.A.
NT ungrazed vs grazed (2-3 vs 4)	0.96	0.04	0.90	0.24
NT monoculture vs rotation (2 vs 3)	0.11	N.A.	0.21	N.A.

Table 2.
Mean cotton lint and corn grain yields and their water-use efficiencies averaged across three Major Land Resource Areas (i.e., Blackland Prairie, Coastal Plain, and Southern Piedmont) during 50 years of simulation by the EPIC model.

SUMMARY AND CONCLUSIONS

- Simulations with the uncalibrated EPIC v. 3060 strongly suggested that no-tillage management of cropland in the southeastern USA would lead to significant sequestration of soil organic C compared with conventional-tillage management.
- Increasing crop rotation diversity did not significantly alter simulated soil organic C sequestration and cotton lint water-use efficiency.
- Relationships between the Soil Conditioning Index and EPIC-simulated SOC sequestration during 50 years suggested that EPIC-simulated SOC sequestration would be highly significant with relatively small changes in positive values of the Soil Conditioning Index.
- Long-term changes in soil organic C appeared to be reasonably well predicted with both EPIC v. 3060 and the Soil Conditioning Index.
- These prediction tools will be of great importance to land managers and policy makers for making decisions that improve soil quality for future use, but there is still an urgent need for long-term, field-based data to validate them.